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Description

This invention relates generally to lasers and more particularly to tunable external cavity semiconductor lasers. In the following discussion, the first digit of a reference numeral will indicate the first figure in which is presented the element indicated by that reference numeral.

Definitions

The "optical axis" of a laser beam is an axis parallel to the direction of the laser beam and centered laterally within the beam.

A "Gaussian beam" is an optical beam in which the power density exhibits a substantially Gaussian distribution as a function of perpendicular distance from the optical axis.

An "elliptical Gaussian beam" is one in which, in a plane perpendicular to the optical axis, the locus of points of the beam at which the power density of the beam is $1/e^2$ of the power density on the optical axis, has an elliptical shape.

A "laser spot", on a plane intersecting a laser beam, is the portion of a laser beam, incident on that plane with a power density greater than $1/e^2$ of the power density on the optical axis of the laser beam.

A "circular Gaussian beam" is an elliptical Gaussian beam in which the laser spot, on a plane perpendicular to the optical axis, is circular.

A "meridional plane" is a plane containing the optical axis.

At a given point on the optical axis, a "principal meridional plane" is a meridional plane that contains one of the elliptical axes of the laser spot on that plane. These two principal meridional planes are perpendicular.

In a laser system having a diffraction grating retroreflector, the "parallel meridional plane" is parallel to the rulings of the diffraction grating and the "perpendicular meridional plane" is perpendicular to the rulings of the diffraction grating.

A "waist" of a circular laser beam occurs at each point along the optical axis at which the wavefronts of light of the laser beam are planar.

In an elliptical Gaussian beam, a "principal meridional plane waist" occurs at each point along the optical axis at which the rays of light of the laser beam are parallel within that principal meridional plane.

An "anamorphic lens system" is one that has a different magnification in two principal meridional planes. For example, anamorphic lens systems are used to compress wide screen motion pictures into a regular film format which can be reexpanded onto the screen by another anamorphic lens system.

An "astigmatic lens system" is one that produces displaced image planes for light propagating in two different meridional planes. For example, a common eye defect is astigmatism in which horizontal lines of a checkerboard can be well focussed while vertical lines are blurred.

A grating is referred to as being in the "Littrow configuration" when it is oriented to retroreflect a selected wavelength of one of its diffraction orders back along the direction of an incident beam of light.

The "wavelength resolution" of a grating tuned external cavity laser is the wavelength range within which the optical feedback from the external cavity to the laser chip is greater than 50% of the peak value of feedback.

A "degenerate cavity" is a retroreflective optical system that always reflects back a given input distribution to coincide with the launched distribution, regardless of the misalignment of the launched distribution.

A "linear laser spot" is an elliptical laser spot in which the elliptical height is much smaller than the elliptical width.

A "nonhomogeneous beam expander" is an element that stretches one lateral dimension of a beam differently than its perpendicular lateral dimension.

A "homogeneous beam expander" expands both perpendicular lateral dimensions of a beam equally.

A laser consists of a Fabry-Perot resonator (cavity) that provides a feedback path through an optical gain element (i.e., an optical amplifier). The optical cavity can contain optical components such as lenses, mirrors, prisms, optical waveguides, filters, etalons, and diffraction gratings. The laser emits optical radiation when it is pumped above a threshold level by an external energy source. This resonator exhibits sufficient gain to lase only in narrow resonant peaks located at a set of discrete optical frequencies. Thus, the laser beam will contain one or more of these discrete frequencies.

Because of the wave nature of light, the laser beam does not have a sharply defined outer perimeter. The parameters that characterize a laser beam are illustrated in Figure 1. In that figure, the z-axis has been selected to coincide with the optical axis 11 of a Gaussian beam 12.

In general, the power density in a laser beam exhibits a substantially Gaussian distribution as a function of perpendicular distance from the optical axis. Such beams are referred to as Gaussian beams. In the x-z plane shown in Figure 1A, the locus of points at which the energy density is $1/e^2$ of the energy density on the optical axis at the same value of z is represented by lines 13 and 14. The transverse distance from the z-axis to a point on line 13 or 14 is represented as $r_x(z)$ and is called the spot size of the laser beam in the xz plane.

A region 15 in which lines 13 and 14 are parallel is referred to as a waist of the laser beam. The radius of the beam at the waist is represented as w_{ox} and the z-position of the waist is represented as z_{ox}. The wavefronts 16 of the laser beam exhibit a radius of curvature $R_x(z)$ that is a function of z. In the far-field region (i.e., at distances from the waist much larger than w_o), wavefronts 16 are substantially centered on a common point P so that the beam appears to be emitted from point P. In the far-field region of a monochromatic laser, lines 13 and 14 diverge at an angle θ_{divx} equal to 2 times the wavelength of the laser beam divided by pi times the waist size w_o.

The distance between point P and a point Q at z_o is called the Rayleigh distance, is referenced as z_{Rx} and is equal to pi times w_{ox} squared divided by the wavelength. Thus, the shape of the Gaussian beam is uniquely defined by the waist position z_o and the waist spot size w_{ox} (see, for example, A. E. Siegman, Lasers, University Science Books, Mill Valley, California 1986).

Optical elements, such as lenses, prisms, and mirrors affect the spot size radius $r_x(z)$ and wavefront curvature $R_x(z)$. Suitable arrangements of these elements can produce additional waists along the optical axis. The matrix math for analyzing the propagation of Gaussian beams through optical systems is well developed and straightforward (see, for example, A. Gerrard and J.M. Burch, Introduction to matrix Methods in Optics, John Wiley and Sons, London, 1975).

In general, a Gaussian beam need not be cylindrically symmetric about the optical axis. In general, the wavefronts will be elliptical and, in any cross-section perpendicular to the optical axis, will exhibit an elliptical spot size. The location z_{ox} of a waist in the xz-plane need not coincide with the location z_{oy} of a waist in the yz-plane. The x- and y-axes can be selected to be respectively oriented along the major and minor principal axes of such ellipse so that the xz and yz planes are the principal meridional planes at that point. When this is done, the Gaussian beam is characterized by the spot size radius $r_x(z)$ in the xz-plane, the spot size radius $r_y(z)$ in the yz-plane, the radius of curvature $R_x(z)$ of the wavefronts in the xz-plane, the radius of curvature $R_y(z)$ of the wavefronts in the yz-plane, the waist location z_{ox} in the xz-plane and the waist location z_{oy} in the yz-plane. In Figure 1B is shown a cross-section of the beam in the yz-plane.

In a semiconductor laser, the semiconductor chip acts as the gain medium and also as a section of optical waveguide. Such a laser may also contain structures that act as mirrors or distributed, wavelength-selective reflectors. If the feedback path is completely contained within the boundaries of the semiconductor chip, the laser is called an internal-cavity semiconductor laser and is illustrated in Figures 2A-2C. These figures respectively illustrate an internal cavity solid state laser, a one-sided external cavity laser, and a two-sided external cavity laser. The internal waveguide terminates at the end faces of the laser chip. From each end face, light is emitted from a small emitting area approximately 1-2 microns across.

It is desirable for a laser to have a narrow linewidth. This linewidth is inversely proportional to the cavity Q, which increases with cavity length. However, because the threshold of a semiconductor chip increases with length, when extended beyond an optimum value, the length L of semiconductor lasers is generally 0.20 - 0.25 mm, resulting in a mode spacing of 1 nm. Since the cavity Q increases with length, limiting the chip length tends to limit the sharpness of the laser linewidth. Also, the wavelength-selective structures that presently can be integrated into a semiconductor chip are not as broadly tunable as optical elements that cannot be integrated into the chip.

In Figures 2B and 2C are illustrated external-cavity lasers (ECL's), so named because part of the feedback path of the laser is external to the semiconductor chip. In an ECL laser, the external elements need to control selection of the laser oscillation wavelength. Therefore, feedback from the external portion of the resonator must dominate feedback from the internal portion of the resonator. To weaken the internal feedback, the end faces can be coated with an antireflection coating to reduce the percent of light reflected at the end faces or they can be tilted so that reflections do not couple back into resonant modes.

In Figure 2B, only one end face is coated with an antireflection coating. The other end face continues to serve as a mirror. This embodiment is a one-sided ECL. In Figure 2C, both end faces are coated with an antireflection coating and two external feedback paths are included. This is a two-sided ECL.

Each external feedback section generally includes a relay optics section and a retroreflector. The components of the relay optics section generally collect, direct, and transmit light from the emitting area of the chip face onto the retroreflector and then back onto the emitting area. Although the following discussion will be in terms of planar emitting and retroreflecting surfaces, the following analysis also applies to those cases in which these surfaces are nonplanar. For example, a curved retroreflector can be replaced by a planar retroreflector plus a lens and then the lens portion of this modified retroreflector can be grouped as part of the relay optics.

For tunability, either a wavelength-selective retroreflector (e.g., a diffraction grating) can be used or a transmitting filter can be included in the relay optics section. To achieve strong external feedback, the external feedback section: (1) should have low loss; (2) should focus the fed-back light onto a spot the same size as the emitting area; and (3) the fed-back spot must overlap the emitting area.

In a diffraction grating tuned laser (as illustrated in Figures 3 and 4), a grating 31 is mounted in a holder that is rotatable about an axis P that is substantially parallel to the axis 32 that is parallel to the rulings 33 of the grating. Since the grating diffracts the incident beam into a multiplicity of spectral orders (illustrated in Figure 4) that are each spread over a small range of angles about axis P, each of these orders can be used as the retroreflected beam. Wavelength selection is then achieved by rotation of the grating about this rotation axis P to sweep this order across the emitting surface of the laser. Unfortunately, perfect alignment of this rotation axis P with the direction 32 of grating rulings 33 is not possible so that rotation about axis P will also produce some tilt of the grating about an axis T that is coplanar with the grating and perpendicular to rotation axis P. Because of the small diameter of the laser beam relative to the separation of the grating from the laser emitting surface, the amount of coupling from the grating back to the laser is very sensitive to rotation about the T axis. This makes such a laser system sensitive to mechanical shock and vibration in addition to rotations about the P axis for selection of the laser wavelength.

For long term output power stability and for tuning over a broad range, grating 31 must be intentionally rotated about the T-axis to compensate for undesired rotation of rulings 33 about the T axis when the grating is rotated about the P-axis. This tight alignment tolerance makes it difficult to design a rugged commercial grating tuned external cavity laser system.

Presently, continual alignment is maintained by manual or electromechanical adjustment of the grating about the P-axis. Unfortunately, manual adjustment is slow, requires continual intervention of a skilled operator and does not lend itself to remote programmed operation. Electromechanical adjustment has a limited response bandwidth and is affected by the general problems of servo-mechanisms (e.g., mechanical shock may push alignment outside the capture range of the servo loop).

In Figures 2B and 2C, respectively, are illustrated side views of one-sided and two sided external cavity lasers. Figure 3 is a perspective view of the one-sided external cavity laser of Figure 2B, for the special case in which the retroreflector is a diffraction grating. Each external cavity includes a relay optics section and a retroreflector. For strong feedback, at each retroreflector, the wavefront (i.e., surface of constant phase) of the laser beam must coincide with the surface of the retroreflector.

That this condition is necessary for strong feedback can be seen as follows. Each point of a wavefront travels in a direction perpendicular to the wavefront at that point. At the retroreflector, if this wavefront has the same shape as the retroreflector's reflecting surface, then the direction of travel of that point in the wavefront is normal to the reflecting surface and is therefore reversed by the reflecting surface. When this happens across the entire surface of the wavefront, each point of the wavefront is retroreflected back along the same path that it travelled from the laser to the retroreflector. This results in the laser beam arriving back at the laser emitting surface in phase across the entire beam. In addition, because each ray of the beam retraces its path from the laser to the retroreflector, the retroreflected beam will have a spot size at the laser equal to the size of the laser emitting surface. This is important not only in directing substantially all of the selected wavelength of light back into the laser, but is also important in this light matching the mode of the laser responsible generation of that mode. The mathematics of the reference by Siegman can be used to prove these results.

When the laser emitting surface is planar, the laser beam has a waist in both principal meridional planes at this surface. When the retroreflector's reflecting surface is planar, the requirement that the wavefront at the retroreflector have the same shape as the retroreflecting surface is satisfied if and only if the beam exhibits a waist at the retroreflecting surface in both principal meridional planes.

An incident wavefront of the beam will coincide with the reflecting surface of the retroreflector only if the retroreflector is carefully aligned with respect to the laser beam. The tolerance to angular misalignment of the retroreflector is determined by the divergence angle of a diffraction order of the grating. If the grating is rotated by 1/2 of the divergence angle, then the intensity of the beam onto the emission face of the laser will be less than $1/e^2$ of the peak intensity of the beam, thereby severely degrading feedback to the chip laser. As indicated in Figure 1, the divergence angle is inversely proportional to the lateral dimension of the source of the Gaussian beam. For the diffraction order directed back to the chip laser, the source for this diffraction order is the laser spot imaged onto the diffraction grating. Therefore, the tolerance to misalignment to rotation of the grating about the P-axis is inversely proportional to the width $2W_p$ of the laser spot on this grating.

As illustrated in Figure 4, a diffraction grating 31 diffracts an incident light beam 42 into multiple diffraction orders (such as orders 43 and 44). In a grating tuned laser system, grating 31 is rotationally oriented about an axis P (that is parallel to the rulings 33 of grating 41) to retroreflect light in a single one of these orders back to the laser. This retroreflecting configuration is known as the Littrow configuration. The profile of each of the grating rulings 33 is typically selected to make this retroreflected order much stronger than the other orders. Wavelength selection for the laser is achieved by rotation of the grating about the P axis.

In Figure 4, the axis perpendicular to the grating face 46 is designated as the N-axis and the axis that is perpendicular to both the P- and N-axes is designated as the T-axis. The axis of incident beam 42 is referred to herein as the optic axis A, the AP plane is referred to herein as the parallel meridional plane and the AT plane is referred to herein as the perpendicular meridional plane. In the perpendicular meridional plane, the grating disperses light according to the Bragg condition. In the parallel meridional plane, the grating acts like a mirror. Thus, misalignment of the grating about the T-axis will tilt the retroreflected beam away from the laser emitting surface, severely degrading operation of the laser.

The wavelength resolution of a grating tuned external cavity laser system is proportional to the number of rulings 33 covered by incident laser beam 42 and is therefore proportional to the width ($2W_T$), in the T-direction, of the laser spot 47 on grating face 46. Therefore, in accordance with the illustrated preferred embodiments, an anamorphic relay section is used to produce on grating face 46 a spot 47 having a height ($2W_p$) much smaller than its width ($2W_T$) so that the laser is much less sensitive to rotations about the T-axis than about the P axis. Spot 47 is substantially elliptical so that the height $2W_p$ and the width $2W_T$ are just the lengths of the minor and major axes of elliptical spot 47. As indicated above, an anamorphic optical section has different magnifications in the two principal meridional planes (see, the reference by A.E. Siegman). Such a section will typically include anamorphic and/or astigmatic elements. As indicated above, an astigmatic optical element produces displaced image planes for light propagating in two different meridional planes.

To ensure that the tuning behavior of the external cavity laser is dominated by the mode structure of the external cavity rather than that of the cavity internal to the semiconductor chip laser, the external cavity wavelength resolution must be on the order of or less than one-tenth the chip cavity mode spacing (i.e., the wavelength difference between adjacent modes of the chip cavity). For a typical grating pitch (i.e., spacing between adjacent rulings of the grating) of 0.83 microns and a wavelength of 1300 nm, this resolution condition requires a spot width $2W_T$, of the beam on the grating, on the order of or greater than 0.2 cm. If the spot were substantially circular, this spot size would require a rotational alignment tolerance about the T-axis of less than 1 milliradian. Such a tight alignment tolerance is not practical for a low maintenance, rugged device.

In addition to angular misalignment of elements, the laser system is also sensitive to lateral (i.e., perpendicular to the optical axis of the incident beam) and longitudinal (i.e., parallel to the optical axis of the incident beam) misalignment of elements. Figure 5 illustrates the case in which the relay optics is laterally misaligned by a distance δ from the emitting area of the laser amplifier. A lateral misalignment by a distance δ equal to the lateral dimension of the emitting area can severely reduce the feedback from the external cavity. Sensitivity to such misalignment is reduced by selecting the external cavity dimensions so that it forms a degenerate cavity (see, J.A. Arnaud, Beam and Fiber Optics, Academic Press, New York, 1976) as illustrated in Figure 6. A degenerate cavity is a retroreflective optical system that always reflects back a given input distribution to coincide with the launched distribution, regardless of the misalignment of the launched distribution. From the viewpoint of geometrical ray tracing, an arbitrary ray retraces its own path after a single round trip through the system. From the point of view of optical transformation theory (see the reference by A. Gerrard, et al), the degeneracy condition requires that a ray traverse a closed path in a single trip from the emitter to the retroreflector and back to the emitter and that the off-diagonal elements of the overall round-trip ray matrix are zero.

The present invention seeks to provide an external cavity laser with an improved anamorphic relay section.

The present invention relates to a laser system of the type comprising a laser amplifier that emits a laser beam; a grating that receives the laser beam and retroreflects a portion of the laser beam back to the amplifier along an optical axis (A), the grating and the amplifier together defining an external cavity laser, the grating being rotatable about a first axis (P) to tune the amplifier and having a transverse axis (T) that forms an oblique angle with respect to the optical axis (A); and an anamorphic relay section which is operative to shape the laser beam to form on the grating a laser spot having a ratio of height to width much less than one. Such a laser system is disclosed in U.S. Patent 3868590.

Similar systems are disclosed in Applied Physics letters, Vol. 17, No. 2, October 1978 pages 131-136 and in U.S. Patent 4016504. Furthermore, Electronics letters, Vol.21, No. 15, 18 July 1975, pages 658-659 discloses an external cavity semiconductor laser comprising a diffraction grating.

The present invention relates to a grating tuned laser which is characterised in that the relay section comprises an elongated conical lens.

Figures 1A and 1B are top and side views, respectively, of a Gaussian optical beam.

Figure 2A is a side view of an internal cavity laser chip.

Figure 2B is a side view of a one-sided external cavity laser.

Figure 2C is a side view of a 2-sided external cavity laser.

Figure 3 is a perspective view of a grating tuned external feedback laser.

Figure 4 illustrates a pair of orders generated by an incident beam on a diffraction grating.

Figure 5 illustrates the effect of lateral misalignment of optical elements in an external cavity laser.

Figure 6 illustrates a representative degenerate cavity.

Figure 7 illustrates a first embodiment of the present invention with the use of an anamorphic element to produce at a planar grating a laser beam waist having a width parallel to the grating rulings that is much less than its width perpendicular to these rulings; and

Figure 8 illustrates an arrangement used to describe a second embodiment of the present invention.

In Figure 7 is shown an improved grating tuned, external cavity laser. This laser system includes an optical amplifier 71, an anamorphic optical relay section 72' and a planar grating 73 containing a plurality of rulings 74. An optical beam 75 emitted from amplifier 71 is imaged to form a waist at grating 73.

Grating 73 is rotatably mounted to rotate about an axis P that is substantially parallel to grating rulings 74. A set of three orthogonal axes at the grating are designated by P (the axis parallel to rulings 74), N (the axis normal to the surface of the grating) and T (the axis perpendicular to axes P and N).

Typically, amplifier 71 has an emitting surface that is approximately circular. Therefore, to produce such an elongated image on the grating, optical relay section 72' is anamorphic and typically contains anamorphic and/or astigmatic elements. Optical relay section 72' includes a cylindrical symmetric lens 76 of focal length f_1 and a conical lens 87 constituting an anamorphic optical element. Laser beam 75 forms a substantially circular laser spot 78 on lens 76 and a substantially circular laser spot 79 on lens 87, but forms a highly elongated cylindrical laser spot 710 on the front face 711 of grating 73. Since the height W_P of spot 710 is much smaller (i.e., on the order of or less than one- length) of the width W_T of spot 710, this laser system is much less sensitive to misalignment of the grating about the T axis than to rotations about the P axis to tune the laser. The extreme ellipticity of the laser spot on the grating means that this spot has substantially the shape of a line and will be referred to herein as a "linear spot".

In the Littrow configuration, axis N typically forms an angle Θ on the order of 50° with the optical axis A of the laser beam. Because of this, all points of grating 73 are not at the same distance along the optical axis.

Because the conical lens 87 has a smaller radius of curvature at an end 88 than it does at another end 89, the focal length f_3 at end 88 is smaller than the focal length f_4 at end 89. This enables axis L' of lens 87 to be oriented at a different angle Φ from optical axis A than the angle $\Theta + \pi/2$ between axis T and the optical axis A. In particular, the angle Φ can be selected such that L' is perpendicular to the optical axis A for all angles Θ between the N axis and optical axis A. Optimisation of the degree of focusing over the tuning range of this laser system is substantially achieved by selecting f_3 and f_4 to focus the entire laser spot 710 on the front face 711 of grating 73 at the midpoint Θ_m of the range of tuning angles Θ.

The z axis coincides with the optical axis A, the x axis is parallel to the P axis and the y axis form a right-handed triad with the x- and z-axes. By "projective distance" between two elements in Figure 7 is meant the difference in z-coordinate between two points on these two elements with the same x- and y-coordinate values. D_1 is the projective distance between end 88 of lens 87 and its projective (in the z-direction) image on grating 73. D_2 is the projective distance between end 89 of lens 87 and its projective (in the z-direction) image on grating 73. f_3 and f_4 are respectively chosen to equal D_1 and D_2 for $\Theta = \Theta_m$ (where Θ_m is the midpoint of the angular range over which the grating is rotated to tune the laser). For the particular choice of (on z-axis) separations between elements 71, 76 and 87 shown in Figure 7, the external cavity of this laser system is degenerate for $\Theta = \Theta_m$ and is therefore insensitive to small translational misalignment of the elements of this system.

In an alternative embodiment, conical lens 87 can be mounted on a rotatable spindle aligned along a rotational axis P''. The anamorphic element 87 can be made to rotate equally with grating 73.

For high efficiency, it is advantageous to use a lens 76 with a small focal length f_1 to capture a high fraction of the light from the laser. However, such a lens 76 produces a collimated cylindrical beam of smaller lateral dimensions than the width W_T of the desired laser spot on the diffraction grating 73. Therefore, optical elements are needed in the optical relay to expand the laser beam.

In Figure 8 is shown an arrangement used to describe additional embodiment of a grating tuned external cavity laser in which optical relay 72 is replaced by an optical relay 72'' that includes a beam expander such as prism pair 811. A "non-homogeneous beam expander" is an element that stretches one lateral dimension of a beam differently than its perpendicular lateral dimension. A "homogeneous beam expander" expands both perpendicular lateral dimensions of a beam equally. Prism pair 811 is an example of a nonhomogeneous beam expander and is used to increase the width W_T of laser spot 710. As in the embodiment of Figure 7, a lens 77 reduces the height W_P of laser spot 710. Although Fig 8 shows the lens 77 as being cylindrical, in the embodiment of the present invention it is conical as shown in Fig. 7. In other embodiments, prism pair 811 can be replaced by a homogeneous beam expander. However, the use of both a nonhomogeneous beam expander to increase W_T and an anamorphic element to decrease W_p produces an increased ratio of W_T:W_P, thereby producing the greatest insensitivity to rotations about the T axis for a given sensitivity to rotations about the P axis.

The above embodiments are also adaptable to systems in which the grating is not planar. In nonplanar gratings, the grating rulings are not parallel lines. For example, in holographic gratings, the lines are just the intersections of the grating surface with a set of hyperboloids produced by interference between a pair of laser beams used in a photolithographic process to produce the grating. For such a grating, the P axis is selected to be maximally parallel to these curving rulings. The P axis will then be referred to as being substantially parallel to these rulings, even though these rulings are curved and only have an average tangential direction parallel to axis P.

Claims

1. A grating tuned laser system comprising a laser amplifier (71) that emits a laser beam (75); a grating (73) that receives the laser beam and retroreflects a portion of the laser beam back to the amplifier along an optical axis (A), the grating and the amplifier together defining an external cavity laser, the grating being rotatable about a first axis P to tune the amplifier and having a transverse axis (T) that forms an oblique angle with respect to the optical axis (A); and an anamorphic relay section (72', 72'') which is operative to shape the laser beam to form on the grating a laser spot (710) having a ratio of height to width much less than one, characterised in that the relay section (72', 72'') comprises an elongated conical lens (87).

2. A system as in claim 1 wherein the ratio of height to width of the laser spot is less than 0.1.

3. A system as in claim 1 or 2 wherein the conical lens (87) has a longitudinal axis (L') and is oriented such that its longitudinal axis is approximately parallel the transverse axis (T) of the grating.

4. A system as in claim 1 or 2 wherein the conical lens (87) has a longitudinal axis (L') and is oriented such that its longitudinal axis is approximately perpendicular to the optical axis (A) at the intersection of the laser beam and the conical lens.

5. A system as in any preceding claim wherein the anamorphic relay section comprises a beam expander (811).

6. A system as in any preceding claim wherein the anamorphic relay section comprises a graded index rod lens (76).

7. A system as in any preceding claim wherein separations between components of the anamorphic relay (72', 72'') are such as to form a degenerate external cavity laser.

Patentansprüche

1. Durch ein Beugungsgitter abgestimmtes Lasersystem, mit einem Laserverstärker (71), der einen Laserstrahl (75) aussendet, einem Beugungsgitter (73), das den Laserstrahl empfängt und einen Teil des Laserstrahles längs einer optischen Achse (A) zum Verstärker zurückreflektiert, wobei das Beugungsgitter und der Verstärker gemeinsam einen Laser mit externem Resonator definieren, das Beugungsgitter um eine erste Achse (P) drehbar ist, um den Verstärker abzustimmen, und eine Querachse (T) hat, die mit der optischen Achse (A) einen schiefen Winkel einschließt, und einem anamorphotischen Übertragungsbereich (72', 72''), der den Laserstrahl formen kann, so daß er auf dem Beugungsgitter einen Laserpunkt (710)

bildet, dessen Verhältnis von Höhe zu Breite viel kleiner als Eins ist, dadurch **gekennzeichnet,** daß der Übertragungsbereich (72', 72'') eine längliche konische Linse (87) aufweist.

2. System nach Anspruch 1, bei dem das Verhältnis der Höhe zur Breite des Laserpunktes kleiner ist als 0,1.

3. System nach Anspruch 1 oder 2, bei dem die konische Linse (87) eine Längsachse (L') hat und so orientiert ist, daß ihre Längsachse ungefähr parallel zur Querachse (T) des Beugungsgitters verläuft.

4. System nach Anspruch 1 oder 2, bei dem die konische Linse (87) eine Längsachse (L') hat und so orientiert ist, daß ihre Längsachse ungefähr senkrecht zur optischen Achse (A) beim Schnittpunkt des Laserstrahles und der konischen Linse ist.

5. System nach einem der vorangehenden Ansprüche, bei dem der amorphotische Übertragungsbereich einen Strahl-Aufweiter (811) aufweist.

6. System nach einem der vorangehenden Ansprüche, bei dem der amorphotische Übertragungsbereich eine Stablinse mit abgestuftem Index (76) aufweist.

7. System nach einem der vorangehenden Ansprüche, bei dem die Trennungen zwischen Komponenten des amorphotischen Übertragungsbereiches (72', 72'') so ausgebildet sind, daß sie Laser mit einem entarteten externen Resonator bilden.

Revendications

1. Système laser accordé au moyen d'un réseau, comprenant un amplificateur laser (71) qui émet un faisceau laser (75); un réseau de diffraction (73) qui reçoit le faisceau laser et rétroréfléchit une partie du faisceau laser en direction de l'amplificateur le long d'un axe optique (A), le réseau de diffraction et l'amplificateur définissant ensemble un laser à cavité extérieure, le réseau de diffraction pouvant tourner autour d'un premier axe P de manière à accorder l'amplificateur et possédant un axe transversal (T) qui est oblique par rapport à l'axe optique (A); et une section relais anamorphique (72',72''), qui agit de manière à mettre en forme le faisceau laser pour former sur le réseau de diffraction une tache laser (710) dont le rapport de la hauteur à la largeur est très inférieur à un, caractérisé en ce que la section relais (72',72'') comporte une lentille conique allongée (87).

2. Système selon la revendication 1, dans lequel le rapport de la hauteur à la largeur de la tache laser est inférieur à 0,1.

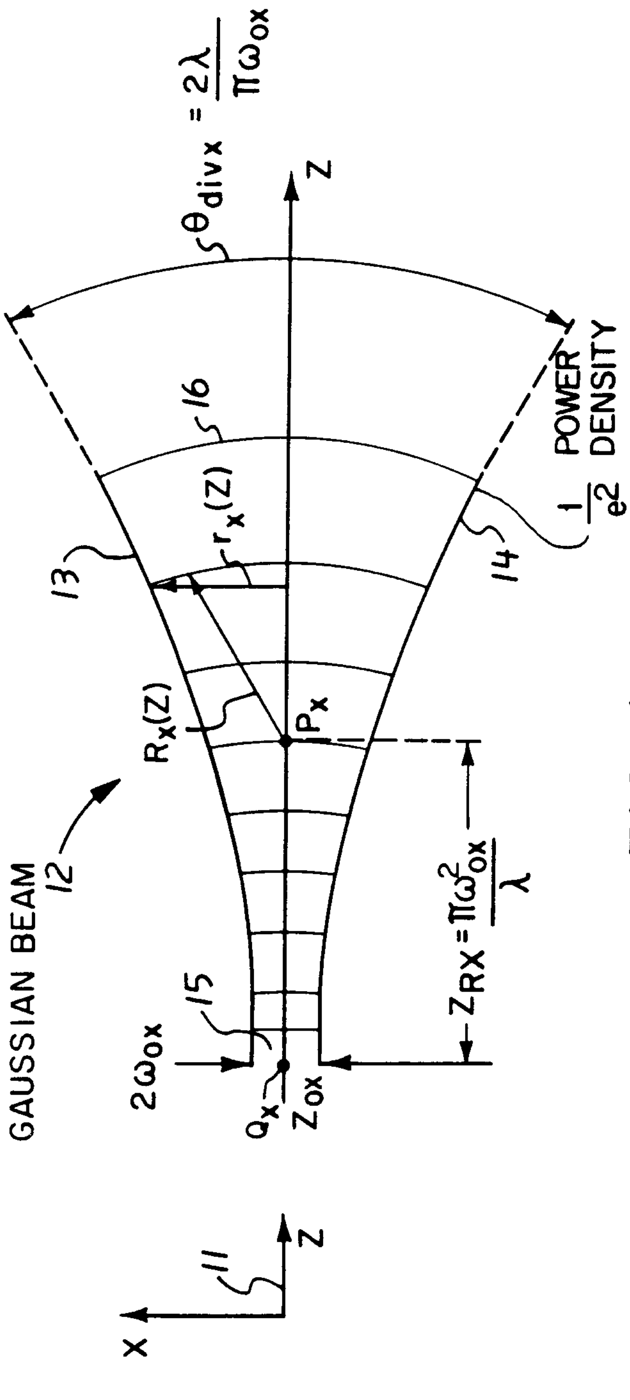
3. Système selon la revendication 1 ou 2, dans lequel la lentille conique (87) possède un axe longitudinal (L') et est orienté de tele sorte que son axe longitudinal est approximativement parallèle à l'axe transversal (T) du réseau de diffraction.

4. Système selon la revendication 1 ou 2, dans lequel la lentille conique (87) possède un axe longitudinal (L') et est orientée de telle sorte que son axe longitudinal est approximativement perpendiculaire à l'axe optique (A) à l'intersection du faisceau laser et de la lentille conique.

5. Système selon l'une quelconque des revendications précédentes, dans lequel la section relais anamorphique comporte un expanseur de faisceau (811).

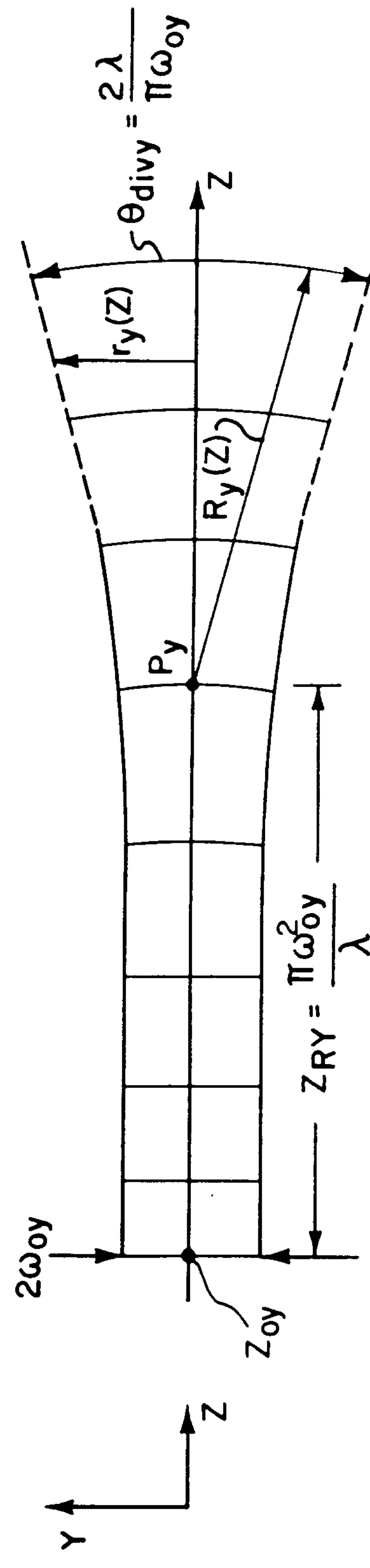
6. Système selon l'une quelconque des revendications précédentes, dans lequel la section relais anamorphique comprend une lentille cylindrique (76) à gradient d'indice.

7. Système selon l'une quelconque des revendications précédentes, dans lequel des séparations entre les composants du relais anamorphique (72',72'') sont telles qu'elles forment un laser à cavité externe dégénéré.



GAUSSIAN BEAM
12
13
14
15
16
POWER DENSITY
$\frac{1}{e^2}$
$\theta_{divx} = \frac{2\lambda}{\pi\omega_{ox}}$
$r_x(Z)$
$R_x(Z)$
P_x
Q_x
Z_{ox}
$2\omega_{ox}$
$Z_{RX} = \frac{\pi\omega_{ox}^2}{\lambda}$
X
Z
11

FIG 1A



$\theta_{divy} = \frac{2\lambda}{\pi\omega_{oy}}$
$r_y(Z)$
$R_y(Z)$
P_y
Z_{oy}
$2\omega_{oy}$
$Z_{RY} = \frac{\pi\omega_{oy}^2}{\lambda}$
Y
Z

FIG 1B

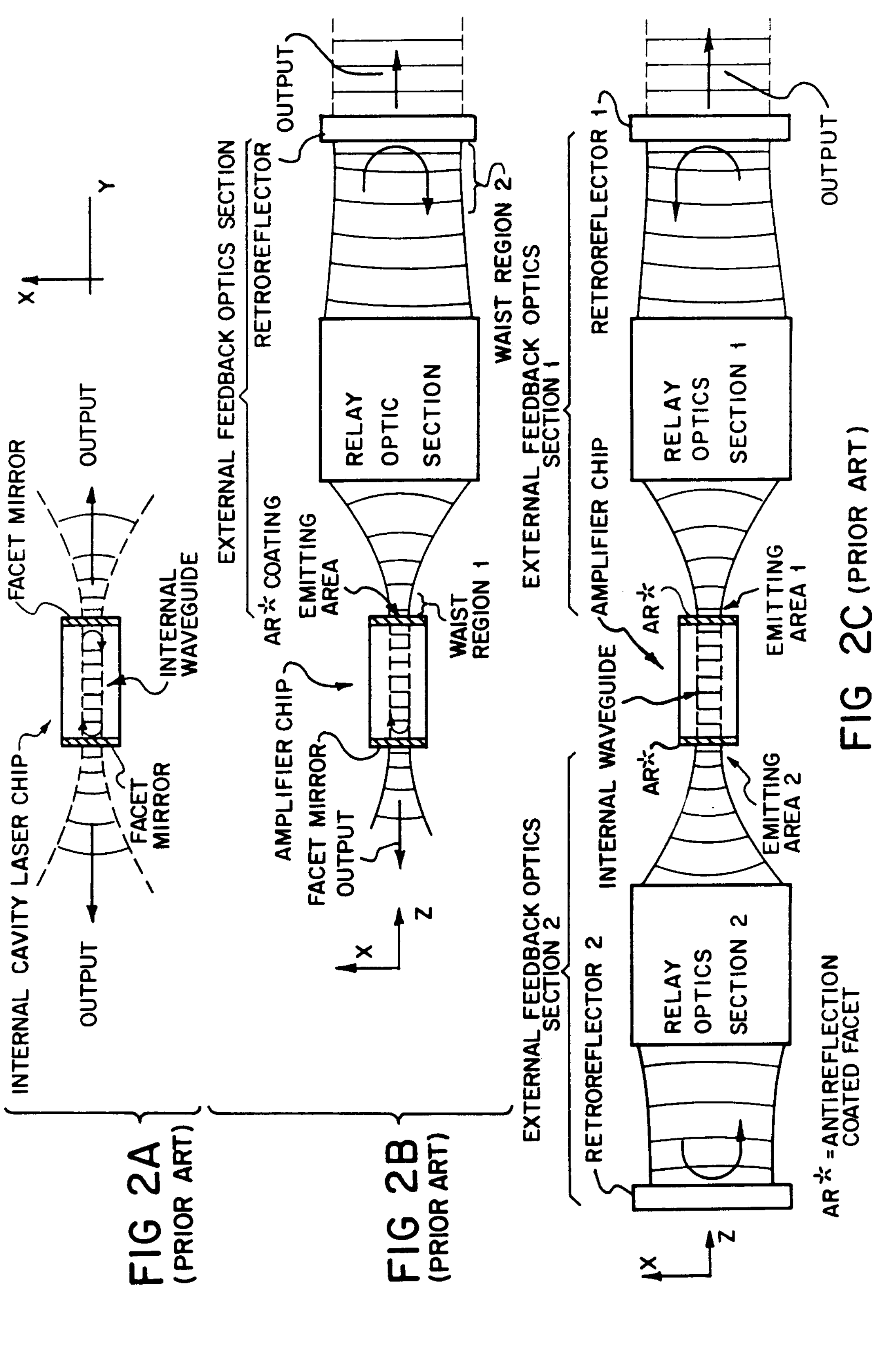


FIG 2A (PRIOR ART)

FIG 2B (PRIOR ART)

FIG 2C (PRIOR ART)

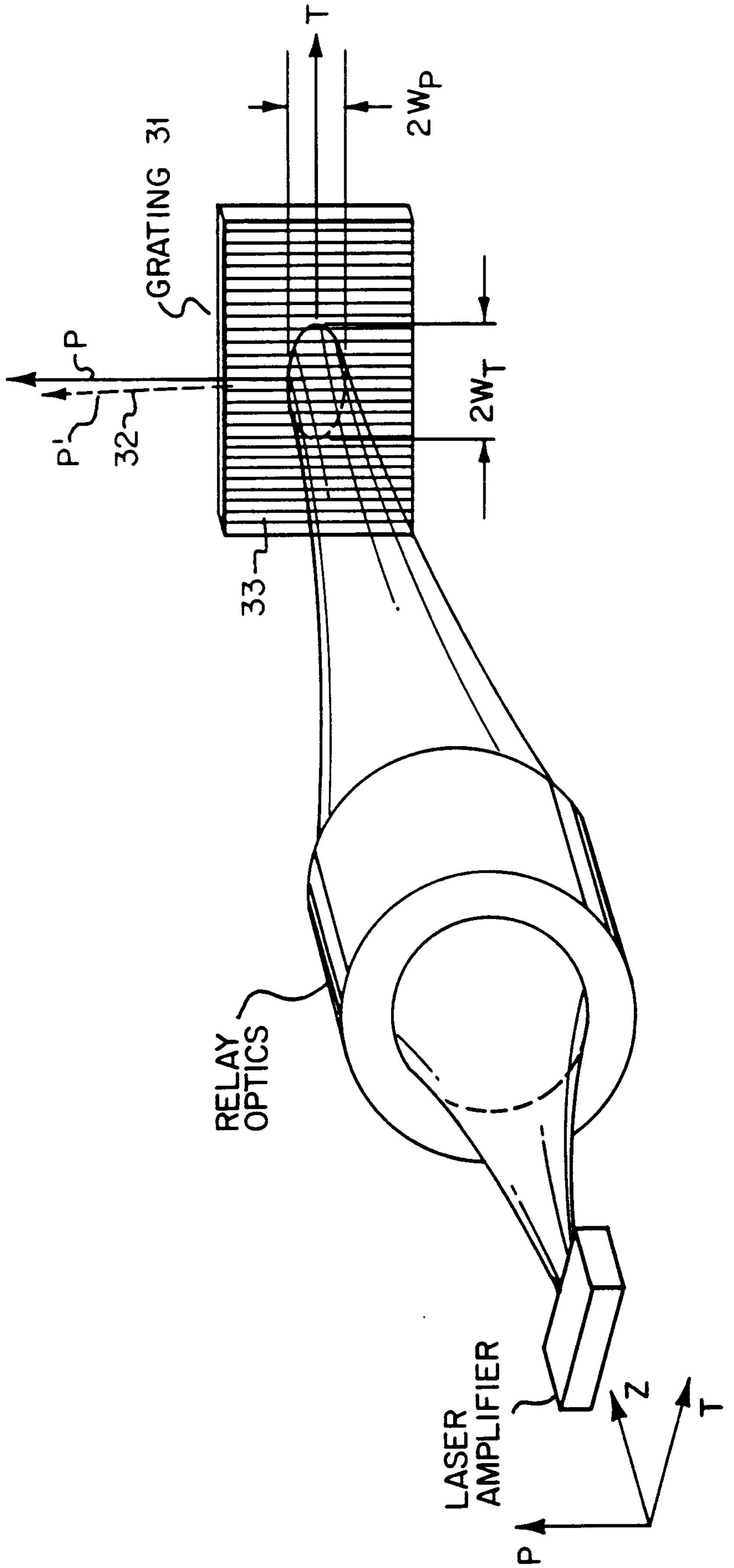


FIG 3 (PRIOR ART)

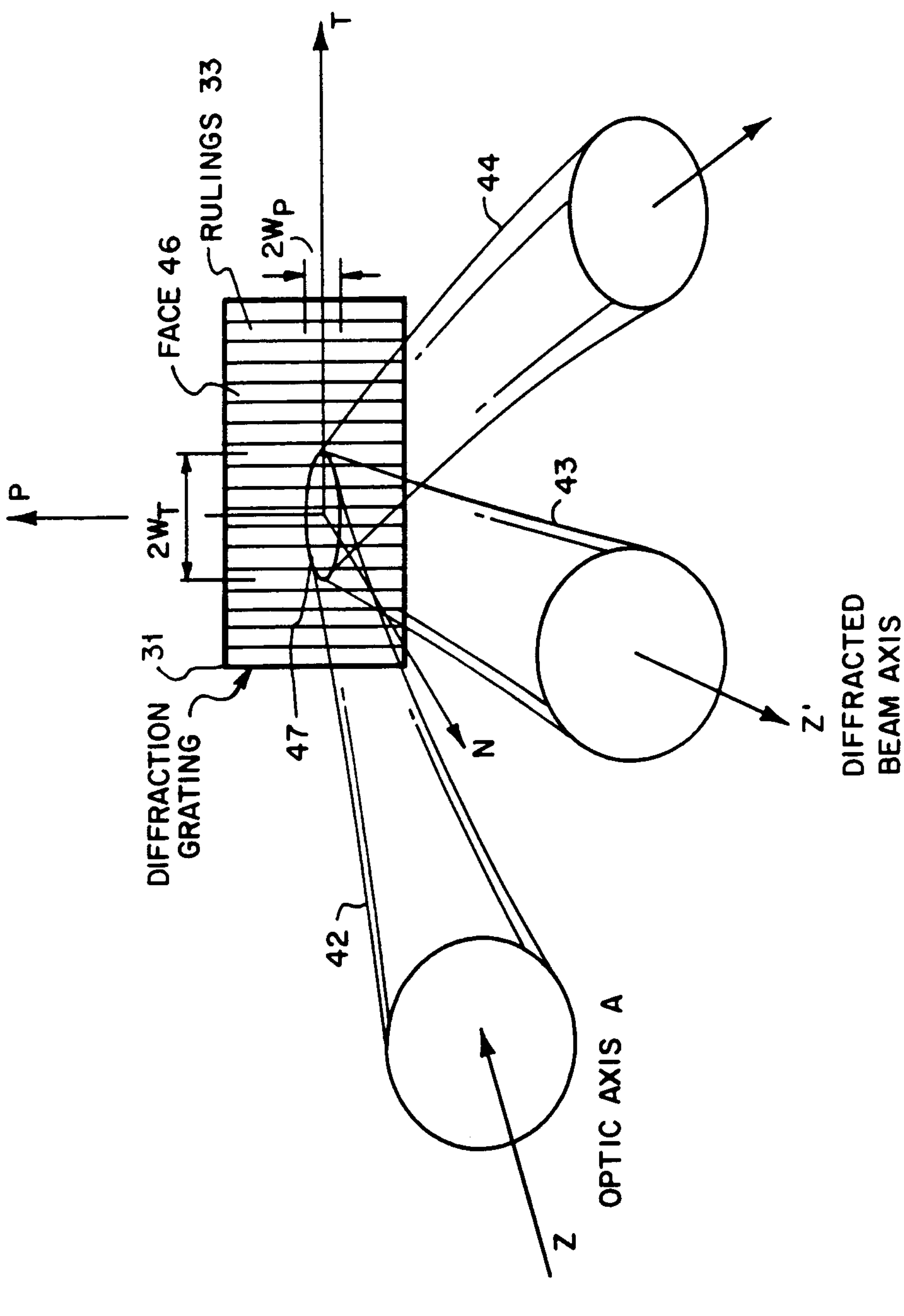
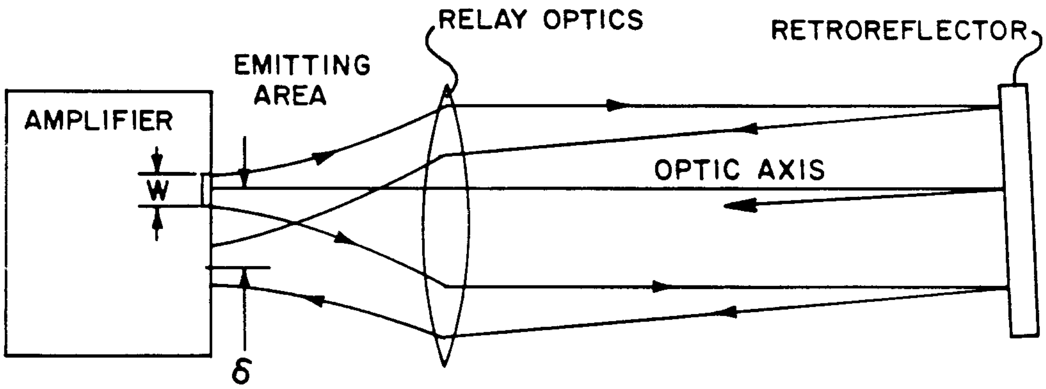


FIG 4 (PRIOR ART)



δ = LATERAL MISALIGNMENT DISTANCE
W = EMITTING AREA SPOT SIZE

FIG 5 (PRIOR ART)

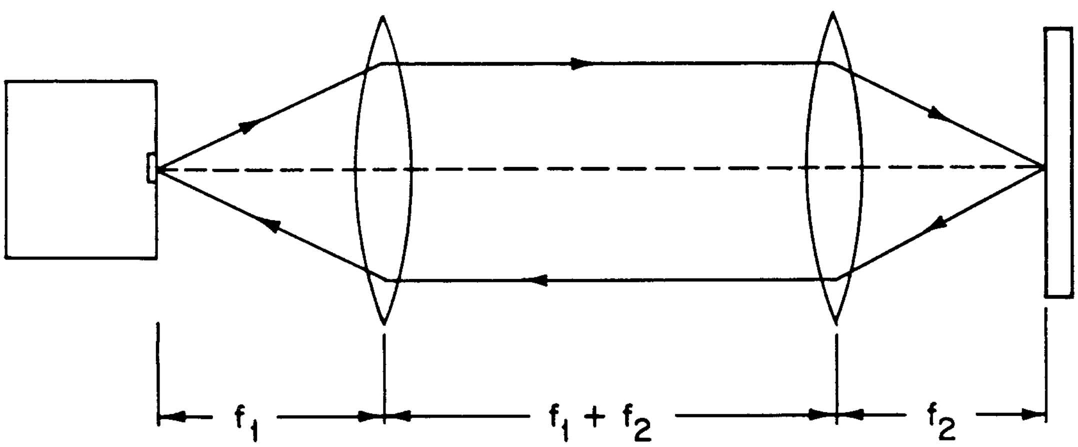


FIG 6 (PRIOR ART)

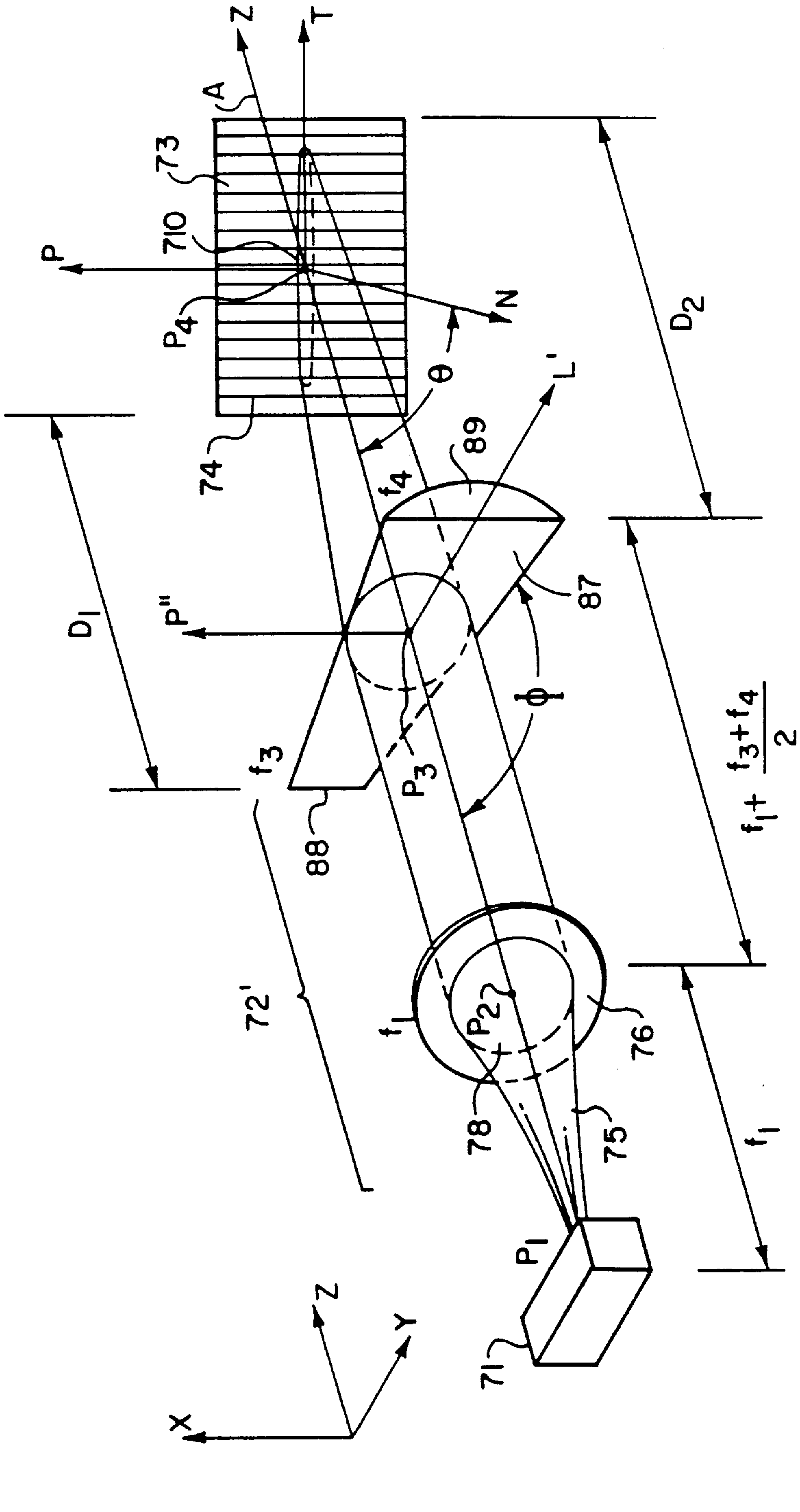

Z
T
A
73
710
P
P4
N
θ
L'
74
89
f4
D2
D1
P"
87
φ
f3
P3
88
f1+ (f3+f4)/2
72'
f1
P2
76
78
75
P1
71
X
Y

FIG 7

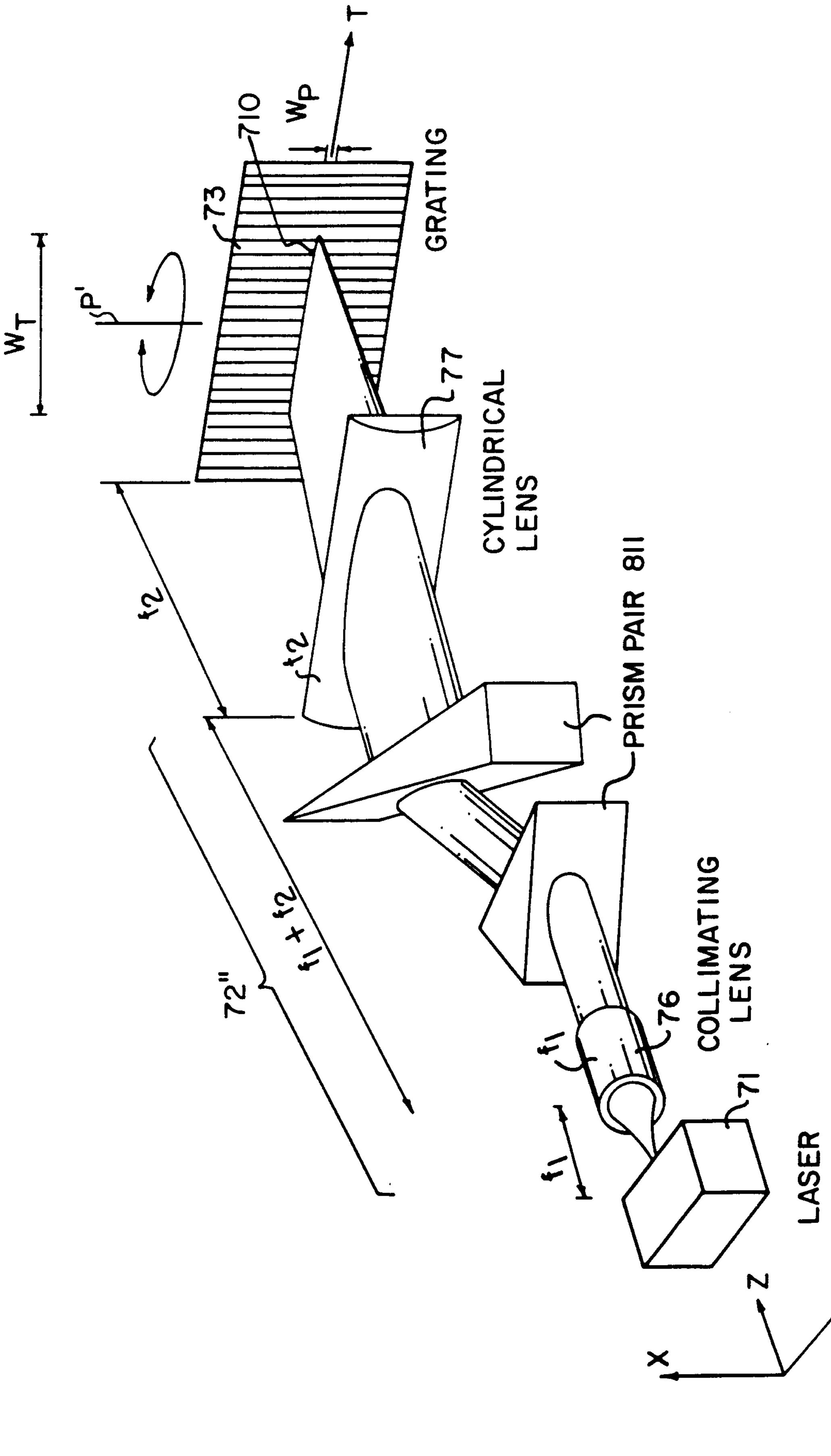

T
WP
710
GRATING
73
P'
WT
77
CYLINDRICAL LENS
f2
f2
PRISM PAIR 811
72"
f1 + f2
COLLIMATING LENS
76
f1
71
f1
LASER
X
Z
Y

FIG 8